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Gegg et al.

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(54) **METHOD FOR SWITCHING OFF A ROTATIONAL SPEED LIMIT IN AN INTERNAL COMBUSTION ENGINE**

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F02D 31/00 (2006.01)

(52) **U.S. Cl.**
CPC ***F02B 63/02*** (2013.01); ***F02D 31/009*** (2013.01)

(58) **Field of Classification Search**
CPC F02B 63/02; F02D 31/009; F02D 37/02; F02D 41/06; F02P 5/1506; F02P 5/1508; F02N 11/087
USPC 123/339.1, 339.14, 350, 399, 406.12, 123/406.18, 406.23, 406.24, 406.53, 123/406.54, 179.3, 179.5, 179.18, 179.28
See application file for complete search history.

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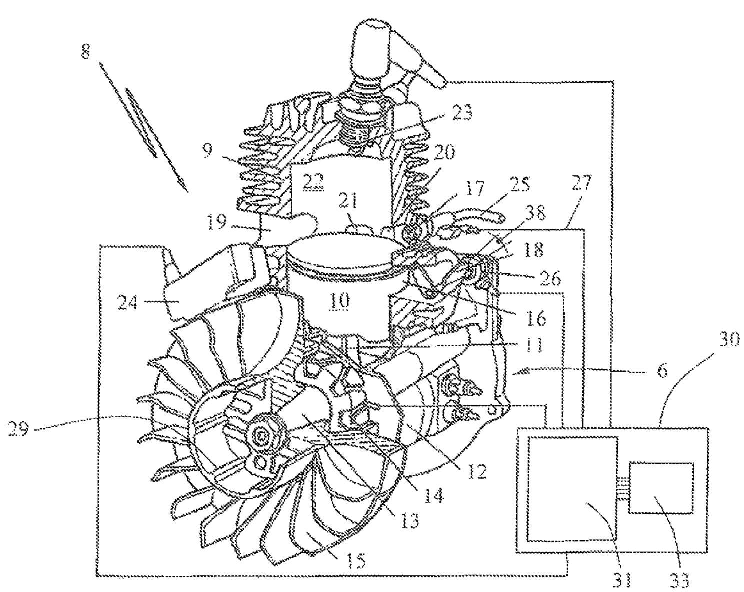
(57) **ABSTRACT**

A method controls the rpm of a combustion engine in a hand-held work apparatus such as a brushcutter. The engine drives a work tool via a clutch which engages as a function of the engine rpm (n). A spark plug is arranged in the combustion chamber and is driven by an ignition unit. During start of the engine, an rpm lock circuit is active and defines a control variable as a function of the instantaneous rpm (n_{act}) of the engine. According to the magnitude of this control variable, operating parameters of the engine are adapted to change the instantaneous rpm (n_{act}). A control variable is determined for the adaptation of the operating parameters by the rpm lock circuit. The switch-off of the rpm lock circuit is provided when the control variable of the control lies outside a predetermined bandwidth of the absolute magnitude of the control variables.

18 Claims, 6 Drawing Sheets



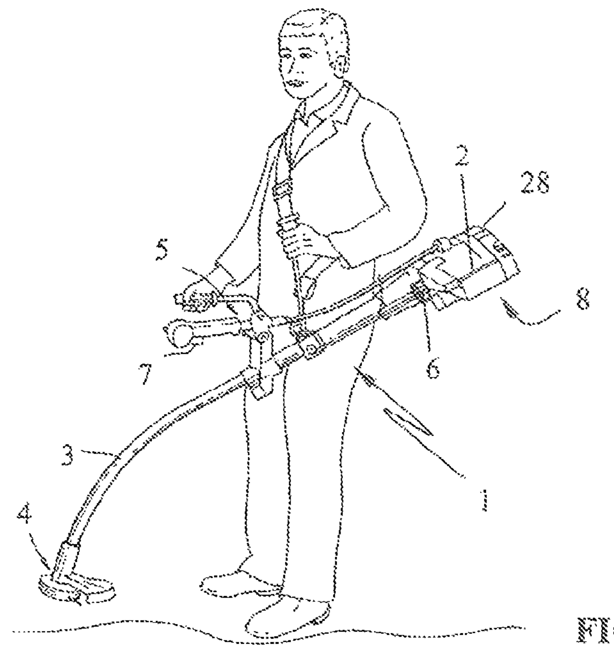
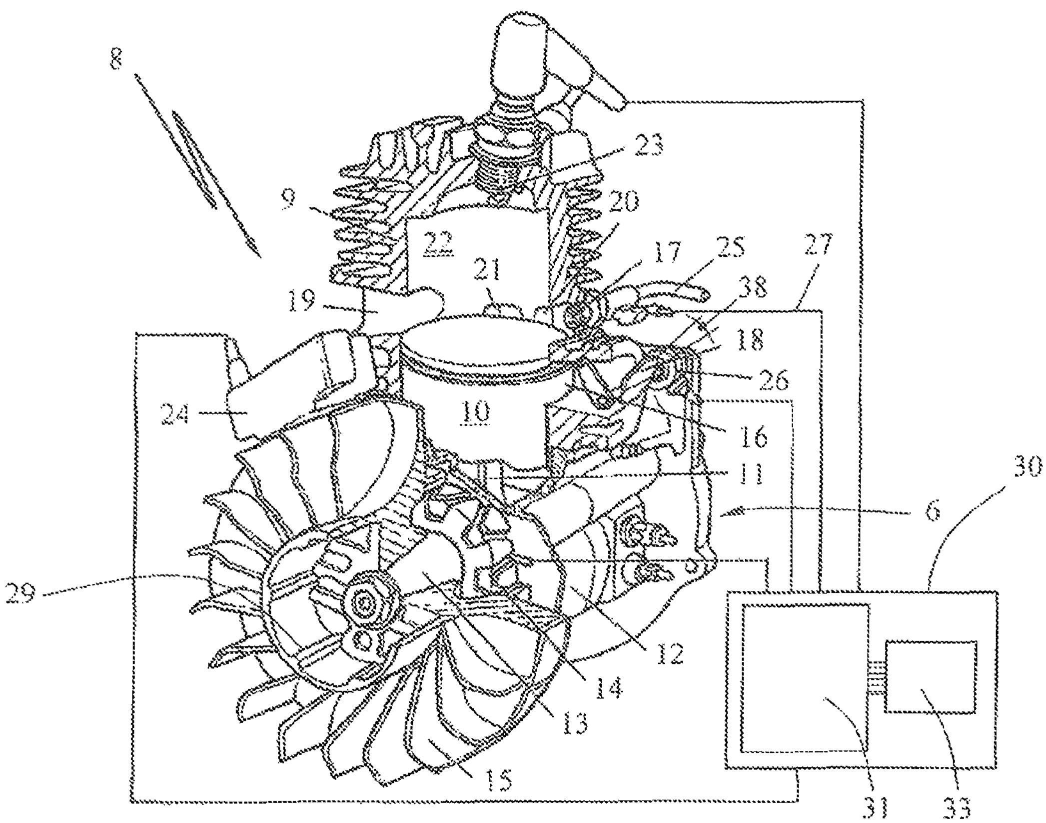

2
28
5
8
7
6
3
1
4

FIG.: 1


8
23
9
20
22
17
25
27
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38
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24
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12
14
13
31
33
15

FIG.: 2

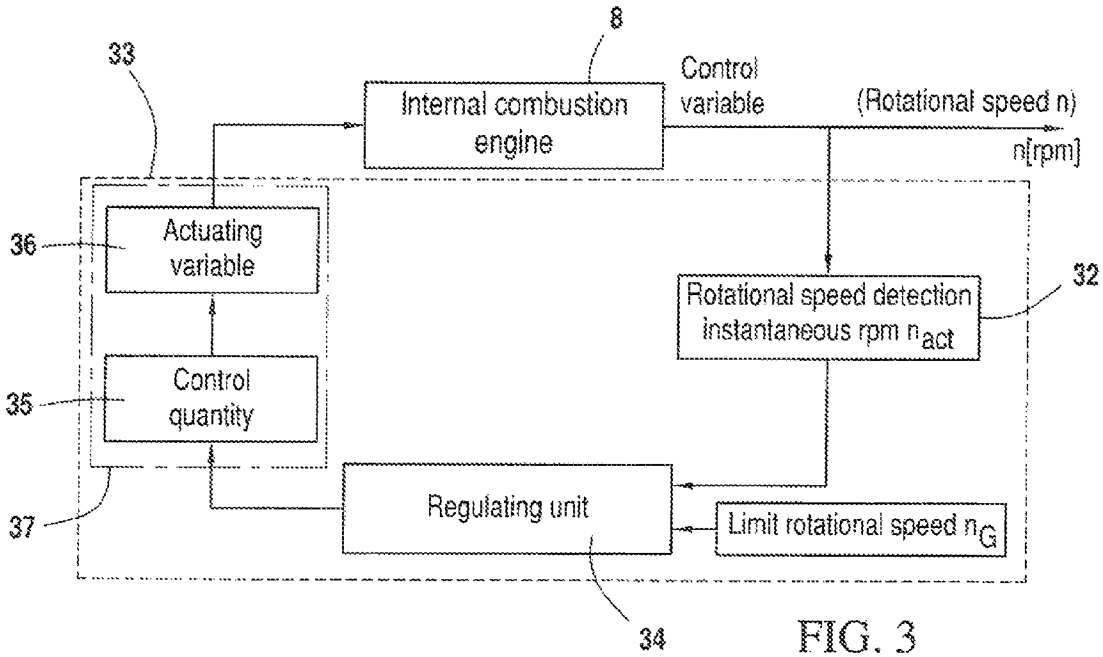


FIG. 3

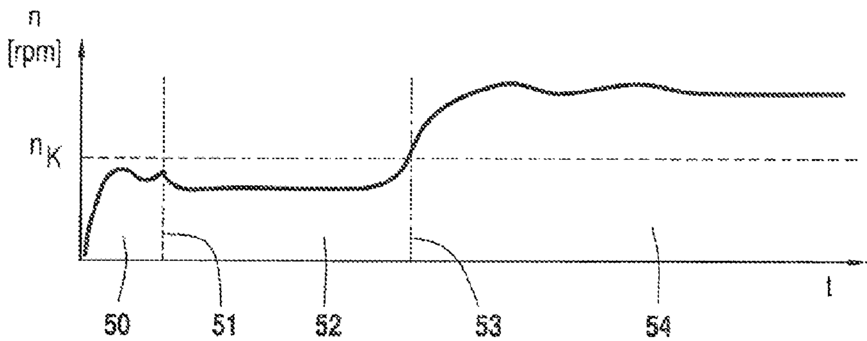


FIG. 5

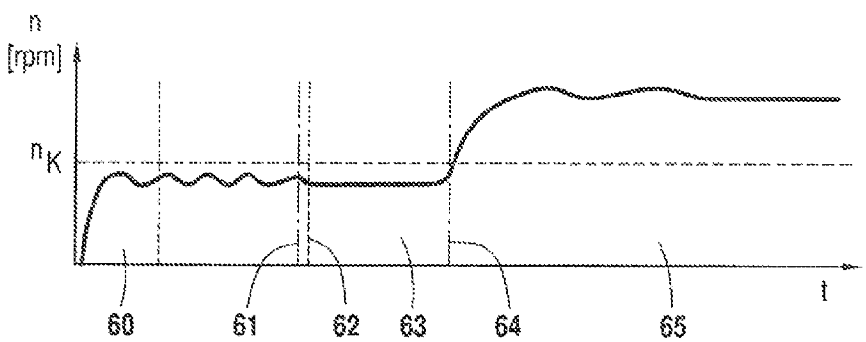


FIG. 6

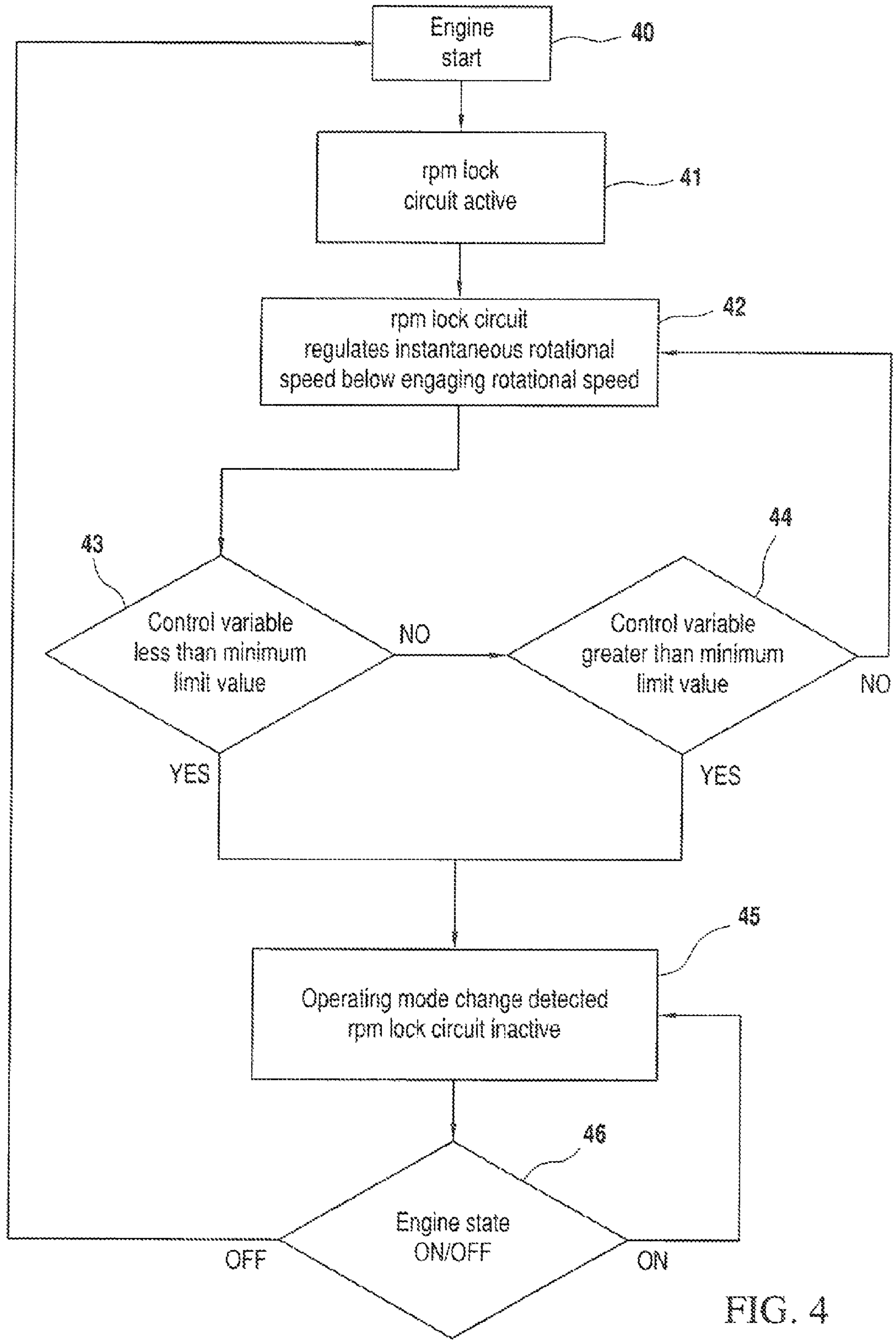
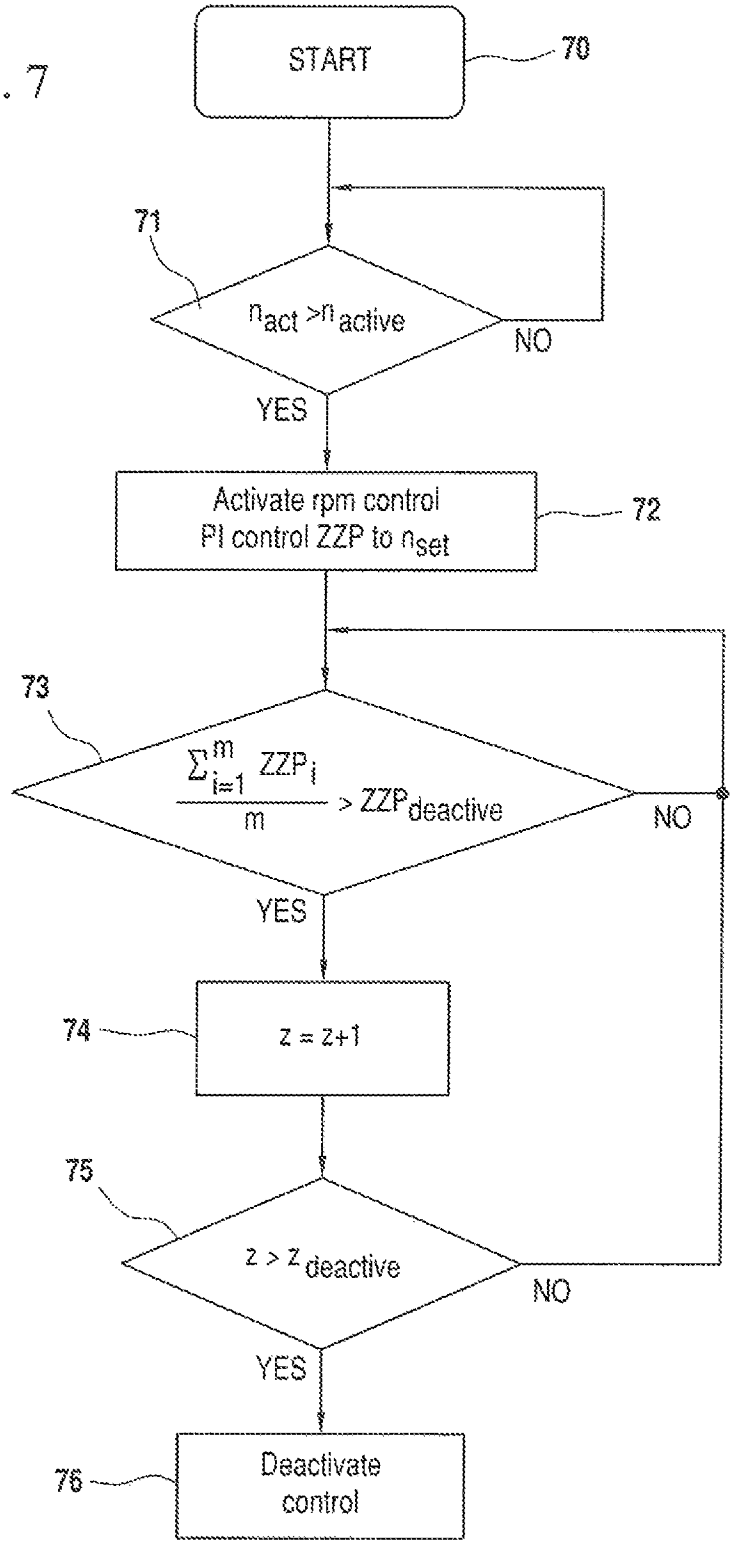

Engine start
40
rpm lock circuit active
41
rpm lock circuit regulates instantaneous rotational speed below engaging rotational speed
42
43
Control variable less than minimum limit value
NO
44
Control variable greater than minimum limit value
NO
YES
YES
45
Operating mode change detected rpm lock circuit inactive
46
Engine state ON/OFF
OFF
ON

FIG. 4

FIG. 7


START
70
71
$n_{act} > n_{active}$
NO
YES
Activate rpm control
PI control ZZP to n_{set}
72
73
$\frac{\sum_{i=1}^{m} ZZP_i}{m} > ZZP_{deactive}$
NO
YES
74
$z = z+1$
75
$z > z_{deactive}$
NO
YES
76
Deactivate control

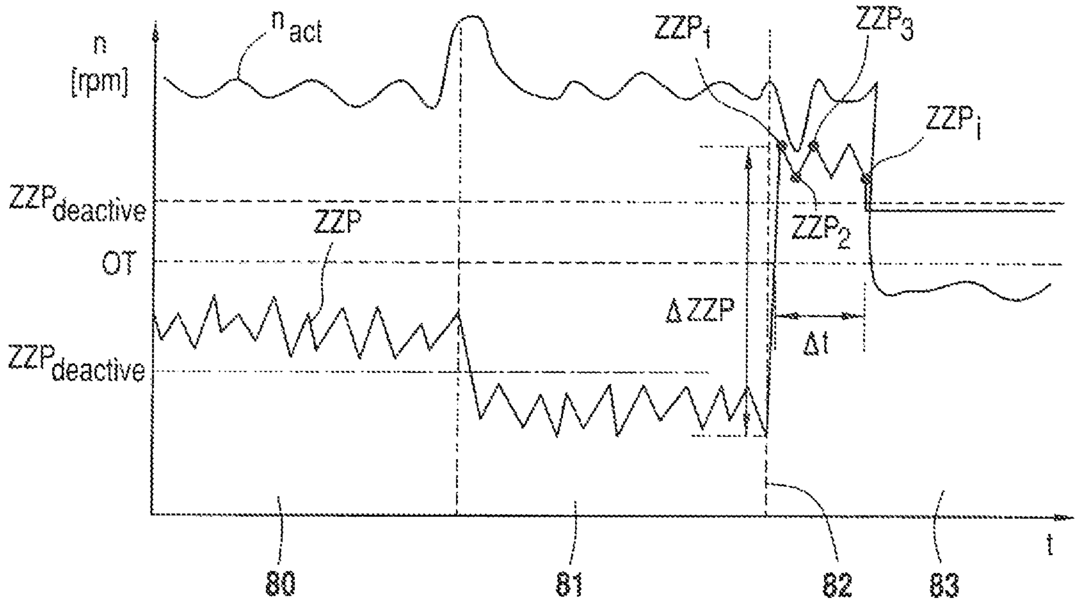

n
[rpm]
n_{act}
ZZP_1
ZZP_3
ZZP_i
$ZZP_{deactive}$
ZZP_2
ZZP
OT
ΔZZP
Δt
$ZZP_{deactive}$
t
80
81
82
83

FIG. 8

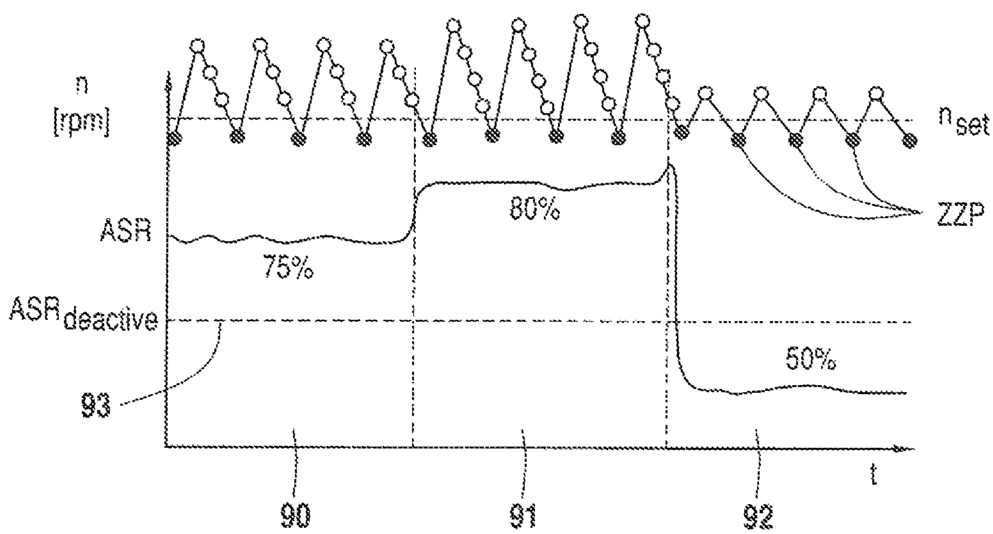

n
[rpm]
n_{set}
ZZP
ASR
80%
75%
$ASR_{deactive}$
50%
93
t
90
91
92

FIG. 9

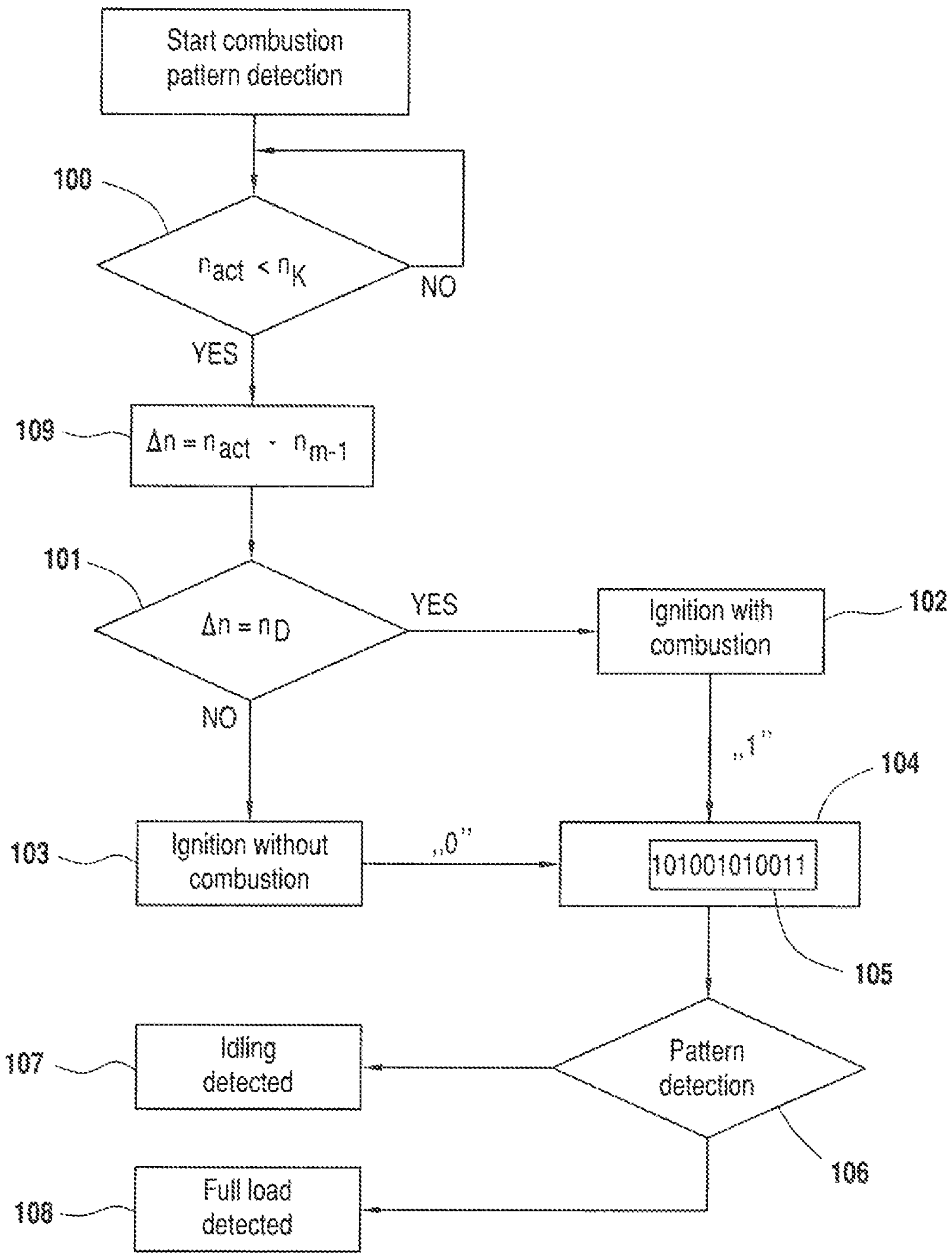

Start combustion pattern detection
100
$n_{act} < n_K$
NO
YES
109
$\Delta n = n_{act} - n_{m-1}$
101
$\Delta n = n_D$
YES
NO
Ignition with combustion
102
„1"
104
103
Ignition without combustion
„0"
101001010011
105
Pattern detection
106
107
Idling detected
108
Full load detected

FIG. 10

METHOD FOR SWITCHING OFF A ROTATIONAL SPEED LIMIT IN AN INTERNAL COMBUSTION ENGINE

CROSS REFERENCE TO RELATED APPLICATION

This application claims priority of German patent application no. 10 2012 015 034.2, filed Jul. 31, 2012, the entire content of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

U.S. Pat. No. 7,699,039 B2 has disclosed a method for switching off a two-stroke engine as soon as the two-stroke engine has achieved stable idling after starting. A rotational speed or rpm lock circuit is active during the start of the internal combustion engine and is deactivated only when the rpm lock circuit has been able to lower the rotational speed of the internal combustion engine below a deactivation rotational speed. This requires a certain time period, within which the user has to give the rpm lock circuit the opportunity to undershoot the deactivation threshold. If the user intervenes in the regulating process by prematurely opening the throttle, the rpm lock circuit remains active and the user cannot increase the rotational speed (rpm) to a working rotational speed.

SUMMARY OF THE INVENTION

It is an object of the invention to provide a method for switching off rotational speed (rpm) limit in an internal combustion engine.

The invention is based on specifying switch-off criteria for the rpm lock circuit for a method, which ensure operationally appropriate, targeted switching off of the rpm lock circuit irrespective of the intervention of the user.

The rpm lock circuit defines a control variable of the regulation as a function of the instantaneous rotational speed of the internal combustion engine. According to the magnitude of this control variable, operating parameters of the internal combustion engine are adapted in order to change the instantaneous rotational speed. According to the invention, the rpm lock circuit is switched off when the control variable of the regulation, which control variable is defined by the rpm lock circuit for adapting the operating parameters, lies outside a predetermined range of the absolute magnitude of the control variables.

The control variable therefore serves not only, in the context of the regulating loop of the rpm lock circuit, for regulating the instantaneous rotational speed itself to a limit rotational speed below the engaging rotational speed, but also according to the invention, moreover, as a criterion for switching off the rpm lock circuit itself.

After a start of the internal combustion engine, if the starting device is switched off and no further intervention is carried out by the user, machine-typical idling which can also be called natural idling will be set as a steady state after a defined number of crankshaft revolutions. The natural idling lies below the engaging rotational speed or the limit rotational speed of the rpm lock circuit, with the result that the control variable of the rpm lock circuit drops below a minimum limit value. If the control variable has dropped below said limit value, this is a sign that natural idling has been set and the rpm lock circuit does not have to intervene further, that is, can be switched off, advantageously after a defined number of further crankshaft revolutions or after a timing element has elapsed.

If, after the start of the internal combustion engine, the user intervenes in the internal combustion engine, with the result that natural idling cannot be set, the rpm lock circuit will stipulate a magnitude for the control variables, which magnitude forces a setting of the rotational speed below the engaging rotational speed or below a limit rotational speed. If the user sets full throttle, although natural idling had not yet been set, the control variable of the regulation will rise above a maximum limit value, from which the conclusion can be drawn that there is an increase in the rotational speed which is forced by the user. Exceeding of an absolute maximum magnitude of the control variables therefore leads according to the invention to switching off of the rpm lock circuit, advantageously after a defined number of further crankshaft revolutions or after a timing element has elapsed.

According to the invention, it is therefore unremarkable whether, at the start of the internal combustion engine, the user accelerates immediately from the start, in order to start working, or first of all waits for natural idling of the machine before he/she increases the rotational speed of the internal combustion engine to a working rotational speed. Since the switch-off criterion of the rpm lock circuit is the control variable which is defined by said rpm lock circuit in the regulating loop, that is to say a control variable or an actuating variable of the regulating loop, the user can start working with the work apparatus immediately after the start of the internal combustion engine without impairment by the rpm lock circuit and can increase the instantaneous rotational speed above the engaging rotational speed.

For the decision as to whether the rpm lock circuit is switched off or not, the absolute value of the control variables is compared with a lower limit value and/or with an upper limit value, which limit values are predetermined for the selected control variable. Undershooting of the lower limit value indicates natural idling; exceeding of the upper limit value indicates intentional acceleration by the user. The teaching of the invention is therefore already implemented when only one limit value is exceeded or undershot.

In one refinement of the invention, the control variable of the regulation of the rpm lock circuit can be the control variable of the regulating loop itself. For example, the air quantity which is fed to the internal combustion engine, the fuel quantity which is fed to the internal combustion engine, the ignition time point or else the off-cycle ratio of the ignition can be utilized as control variable.

As an alternative, the actuating variable of the regulating loop can also be used as control variable, that is to say the variable which is set directly at the internal combustion engine. If, for example, the fuel supply is controlled by a fuel valve, the actuating variable is the opening time of the fuel valve. The number of crankshaft revolutions which follow one another with one ignition can also be an actuating variable, that is to say the rpm lock circuit stipulates, in order to set the instantaneous rotational speed, in which crankshaft revolutions ignition is carried out and in which crankshaft revolutions ignition is not carried out, that is to say what off-cycle ratio is to be set. As an alternative, the actuating variable can also be the ignition time point itself or else the magnitude of the ignition time point shift itself.

In a further, independent solution of the problem, it is provided that the rpm lock circuit changes the ignition time point of the spark plug, as a result of which the instantaneous rotational speed of the internal combustion engine is regulated. During each revolution of the crankshaft, the ignition time point which is set by the rpm lock circuit is compared with a predetermined ignition time point and the rpm lock circuit is always switched off when the ignition time point which is set exceeds the predetermined ignition time point. If the predetermined ignition time point lies before the top dead center of the piston, the rpm lock circuit is always switched off when the ignition time point which is set lies earlier than the predetermined ignition time point.

If the predetermined ignition time point lies in the range of a retarded ignition after the top dead center TDC of the piston, the rpm lock circuit is always switched off when the ignition time point which is set lies later than the predetermined ignition time point.

The rpm lock circuit is expediently not switched off until a predetermined time period is exceeded, preferably not until the ignition time point which is set exceeds the predetermined ignition time point over a plurality of revolutions of the crankshaft which follow one another.

It is also expedient to increase a counter by one increment each time the predetermined ignition time point is exceeded, in order not to switch off the rpm lock circuit until a counter limit value is reached.

The predetermined ignition time point for deactivating the rpm lock circuit advantageously lies before the top dead center of the piston, that is, in the range of advanced ignition.

In one development of the invention, the rpm lock circuit defines the control variable as a function of the instantaneous rotational speed of the internal combustion engine; in particular, the control variable is calculated as a function of the difference of the instantaneous rotational speed of the internal combustion engine from a predetermined limit rotational speed.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described with reference to the drawings wherein:

FIG. **1** shows a work apparatus which is hand-held by a user with the work apparatus being a brushcutter by way of example;

FIG. **2** is a schematic of an internal combustion engine of the work apparatus according to FIG. **1**;

FIG. **3** is a schematic block diagram showing the method of operation of the rpm lock circuit as a control loop;

FIG. **4** is a flow chart of the method according to the invention;

FIG. **5** is a diagram of the rpm plotted as a function of time for the starting operation of an internal combustion engine during idling;

FIG. **6** is a diagram of the rpm plotted as a function of time for a starting operation of the internal combustion engine at full load;

FIG. **7** shows a flow diagram of the sequence of switching off an rpm lock circuit according to a further embodiment of the invention;

FIG. **8** shows a diagram of the rpm of the internal combustion engine plotted as a function of time of the ignition time points relative to the position of the piston;

FIG. **9** is a diagram of the rpm plotted as a function of time with off-cycle of the ignition above a rotational speed threshold; and,

FIG. **10** is a flow diagram for detecting a combustion pattern.

DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

The work apparatus **1** which is shown diagrammatically in FIG. **1** is a brushcutter. This hand-held work apparatus **1** is carried by a user and is an example for other portable, hand-held work apparatus, such as cutoff machines, hedge trimmers, power saws, pole pruners, blower devices or the like.

The work apparatus **1** comprises substantially a guide tube **3** which supports, at one end, an internal combustion engine **8** arranged in a housing **2** and, at the other end, a tool head with a work tool **4**. In the embodiment shown, the work tool is a cutting filament. The work tool can also be a knife blade or the like.

A handle bar **5** which lies transversely with respect to the guide tube **3** and is fastened to the latter is provided for holding and guiding the work apparatus. Operator-controlled elements **7** for controlling the internal combustion engine **8**, which is provided in the housing **2**, are provided on one of the handles of the handle bar **5**. The crankshaft of the internal combustion engine **8** drives the work tool **4** via a clutch **6**, the clutch **6** preferably being configured as a centrifugal clutch. The centrifugal clutch has an engaging rotational speed; above the engaging rotational speed, a rotationally fixed drive connection is produced between the work tool **4** and the crankshaft of the internal combustion engine **8**; below the engaging rotational speed, the drive connection to the crankshaft is interrupted.

The internal combustion engine **8** of the work apparatus **1** is preferably an oil-in-gasoline lubricated internal combustion engine, in particular a single-cylinder two-stroke engine. A configuration as an oil-in-gasoline lubricated four-stroke engine, preferably as a single-cylinder four-stroke engine, can be practical.

FIG. **2** shows an oil-in-gasoline lubricated, single-cylinder two-stroke engine as an example. The internal combustion engine **8** comprises substantially a cylinder **9** and a crankcase **12** wherein the crankshaft **13** is rotatably mounted. A combustion chamber **22** is formed in the cylinder **9** and is delimited by a piston **10** which drives the crankshaft **13** via a connecting rod **11**.

A fan wheel **15** for producing a cooling air flow of the air-cooled internal combustion engine **8** is provided at one end of the crankshaft **13**. A generator **14** is arranged between the fan wheel **15** and the crankcase **12**. The generator **14** provides the electric energy which is necessary for a control unit **30**.

Two transfer channels **20** and **21** open into the combustion chamber **22** and are connected to the crankcase **12**. The fuel/air mixture is conveyed into the combustion chamber **22** via the transfer channels (**20**, **21**) during the downward stroke of the piston **10**. The combustion air, which is necessary for operation, is drawn into the crankcase **12** via an inlet **16** in the region of the top dead center (TDC) of the piston **10**, the air supply being controlled by a throttle valve **18**. The position of the throttle valve **18** is detected via a position sensor **26** which determines the corresponding rotary angular position of the throttle valve **18** of the control unit **30**.

The fuel quantity which is necessary for operation of the internal combustion engine **8** is fed in via a fuel valve **17** which is connected via a fuel line **25** to a fuel reservoir which is preferably at a system pressure. The fuel valve **17** is an electromagnetic fuel valve actuated via a pulsewidth modulated signal. To this end, the fuel valve **17** is connected via a control line **27** to the control unit **30**.

The fuel/air mixture is drawn into the combustion chamber **22** and is compressed when the piston **10** moves upward and is ignited via a spark plug **23**. The spark plug **23** is driven by an ignition device **24** and the ignition time point of the spark plug **23** can be changed by the control unit **30**. After ignition of the fuel/air mixture disposed in the combustion chamber **22** has taken place, the piston **10** moves downward and drives the crankshaft **13** rotationally. When the outlet **19** is open, the combustion gases are discharged via a muffler which is not shown in greater detail.

The control unit **30** comprises an rpm control circuit **31** and an rpm lock circuit **33**. By means of the rpm control circuit **31**, the ignition time point ZZP of the internal combustion engine **8** is selected such that it is adapted to the rotational speed (rpm) and the load condition of the internal combustion engine **8** in order to ensure high-performance operation of the internal combustion engine.

The internal combustion engine **8** is started manually via a pull-rope starter **28** (FIG. **1**). The pull-rope starter **28** acts at the end of the crankshaft **13** whereat the fan wheel **15** is provided. To this end, the fan wheel **15** is configured with an engagement apparatus **29** for the pull-rope starter **28**.

The internal combustion engine **8** can be started, electrically or mechanically, in various throttle positions. It is to be ensured here that, during the starting operation, the rotational speed of the internal combustion engine **8** does not rise above the engaging rotational speed of the clutch **6**. In order to ensure this, the rpm lock circuit **33** is provided which is active during the start of the internal combustion engine **8** and forces the rotational speed of the internal combustion engine below the engaging rotational speed n_K.

The method of operation of the rpm lock circuit **33** is represented diagrammatically in FIG. **3**. In the case of starting, the internal combustion engine **8** runs up, its rotational speed (n) being detected by a detection unit **32** and being reported to the regulating **34** of the rpm lock circuit **33**. Furthermore, the regulating unit **34** is fed a limit rotational speed n_G which is preferably smaller than the engaging rotational speed n_K. The limit rpm or rotational speed n_G preferably lies approximately 500 rpm below the engaging rotational speed n_K.

The regulating unit **34** compares the instantaneous rotational speed n_{act} with the limit rotational speed n_G and, from the difference Δn, derives a control variable **35** which is converted into an actuating variable **36** and which is applied at the internal combustion engine **8**. It is ensured by means of this regulating loop that, during the start of the internal combustion engine **8**, the instantaneous rotational speed n_{act} cannot rise above the engaging rotational speed n_K of the clutch **6**.

The control variable **35** and the actuating variable **36** of the regulating loop are together called control variable **37**. As control variable **35**, for example, the air quantity which is fed to the internal combustion engine **8** can be changed. If the regulating unit **34** has defined the control variable "air quantity", an actuating variable **36** is determined which can be, for example, the magnitude of the rotary angle **38** (FIG. **2**) of the throttle valve **18** in the inlet **16** of the internal combustion engine **8**. The actuating variable **36** which corresponds to the control variable **35**, that is, the rotary angle **38** of the throttle valve **18**, is defined and is set at the internal combustion engine **8**, for example via a stepping motor or the like.

In one embodiment of the invention, it can also be provided to use the ignition time point ZZP as actuating variable **36**, that is, to change the rotational speed and power output of the internal combustion engine by virtue of the fact that the time point of the ignition spark at the spark plug **23** is selected relative to the top dead center position (TDC) of the piston **10**. The regulating unit **34** defines a change in the ignition time point ZZP as control variable **35** as a function of the difference between the instantaneous rotational speed n_{act} and the limit rotational speed n_G. The control variable **35** is used in the rotational speed control circuit **31**, in order to adjust the ignition time point ZZP of the internal combustion engine **8** in accordance with the actuating variable **36**, calculated from the control variable **35**.

Since the rpm lock circuit **33** is active from the start of the internal combustion engine **8** and reliably keeps the rotational speed during the starting operation below the engaging rotational speed n_K, a criterion is required, according to which the rpm lock circuit **33** can be switched off, that is, can be switched to inactive. In FIG. **4**, a flow diagram is shown for switching off the rpm lock circuit **33** after the start of the internal combustion engine **8**.

During the engine start **40**, the rpm lock circuit is active, as specified in box **41**. The rpm lock circuit **33** regulates the instantaneous rotational speed n_{act} below the engaging rotational speed n_K, as specified in field **42**.

Each time that the rpm lock circuit **33** has defined the control variable **37** as regulating variable, a check is made as to whether the control variable **37** lies outside a predetermined range of the absolute magnitude of the control variables **37**. Here, the range is defined by a lower limit value G_{min} and an upper limit value G_{max}. In a first decision diamond **43**, a check is made as to whether the control variable **37** which is defined by the rpm lock circuit **33** is less than the lower limit value G_{min}. If this is not the case, the defined control variable **37** is compared with the upper limit value G_{max}. If the control variable **37** is not greater than the upper limit value G_{max}, the second decision diamond **44** branches back to field **42**; the rpm lock circuit regulates within the permissible range of the control variables **37**.

If the absolute magnitude of the control variable **37** lies below the lower limit value G_{min} or above a maximum limit value G_{max}, the decision diamonds **43** and **44** branch to field **45**, via which the rpm lock, circuit **33** is switched to inactive. Here, it is assumed that the magnitude of the control variables **37** of the regulating loop of the rpm lock circuit **33** permits a conclusion about operating state changes of the internal combustion engine **8**. If the intervention of the regulating loop of the rpm lock circuit **33** can scarcely still be detected, that is, the control variable **37** is very small and lies below the lower limit value G_{min}, the internal combustion engine **8** is in natural idling. From the natural idling, an increase in the rotational speed is expected only when the user applies the throttle, that is, deliberately increases the rotational speed of the internal combustion engine **8**. It is therefore justified during natural idling to switch the rpm lock circuit **33** to inactive.

If in contrast, the control variable **37** is very large, that is to say the decision diamond **44** branches with YES, the control variable **37** is considerably greater than the upper limit value G_{max}; it can be concluded from this that the user is clearly selecting full throttle and desires an increase in the rotational speed (n) beyond the engaging rotational speed n_K. The branch into field **45** can also be followed in this state and the rpm lock circuit **33** can be switched off.

Field **45** branches into a decision diamond **46**, in which a check is made as to whether the internal combustion engine **8** is in operation or is switched off. If the internal combustion engine **8** is in operation, a return is made to field **45**; if the internal combustion engine **8** is switched off, the decision diamond branches back to engine start **40**.

It is therefore provided according to the invention to use the control variable **37** of the regulating loop of the rpm lock circuit **33**, in order to derive a decision about switching off the rpm lock circuit **33** using the magnitude of the control variables **37** (control variable **35** or actuating variable **36**) which are defined for a regulation of the rotational speed.

In FIG. **5**, the rotational speed profile during the start of an internal combustion engine **8** is shown. In section **50**, the internal combustion engine **8** has run out after starting by the pull cord starter **28** and is kept below the engaging rotational speed n_K by the rpm lock circuit **33**; the rpm lock circuit **33** is active. The dotted line **51** indicates the deactivation of the rpm lock circuit **33**. A state which allows idling conditions to be assumed was detected, using the monitoring of the control variables **37** of the regulating loop of the rpm lock circuit **33**. Natural idling has therefore been set in section **52**. The user applies the throttle at the level of the dash-dotted line **53**, for which reason the rotational speed rises above the engaging rotational speed n_K and the work apparatus **1** is used in the full load range **54** with engaged clutch **6**.

In FIG. **6**, the internal combustion engine **8** is started under load, as the fluctuating rotational speed (n) below the engaging rotational speed n_K in section **60** shows. At the level of the dash-dotted line **61**, the start enrichment is switched off, the rotational speed drops, and the rpm look circuit **33** reduces its intervention; the control variable **37** becomes smaller and undershoots the lower limit value G_{min}, for which reason the rpm lock circuit **33** is switched off at the level of the dotted line **62**. Natural idling has been set in section **63**. At the level of the dash-dotted line **64**, the user again applies the throttle, the rotational speed n_{act} exceeds the engaging rotational speed n_K, the clutch **6** engages, and the work apparatus is in section **65** in the work mode.

In the same way as the ignition time point ZZP, the fuel quantity which is fed to the internal combustion engine **8** can also be regulated as control variable **35** in such a way that the instantaneous rotational speed n_{act} does not rise above the limit rotational speed n_G or the engaging rotational speed n_K.

In a corresponding way, the off-cycle ratio ASR of the ignition can also be used as control variable **35**, as is shown at the top in FIG. **9**.

Since the actuating variable **36** for intervention at the internal combustion engine **8** is derived from the control variable **35**, the actuating variable **36** itself can also be used directly as control variable **36** for switching off the rpm lock circuit **33**. If, for example, the control variable **35** was the fuel quantity defined by the regulating unit **34** (FIG. **3**), the opening time of the fuel valve **17** (FIG. **2**) is derived as actuating variable **36**, for example the pulsewidth of the control signal which is fed to the fuel valve **17**.

Accordingly, if the ignition time point ZZP_j is selected as control variable **35**, the ignition time point ZZP_i itself can be used as actuating variable **36** and can be selected directly. No change of the ignition time point by adjustment therefore takes place, but rather the ignition time point ZZP which is defined by the regulation of the rpm lock circuit **33** is set directly. This can be carried out, for example, via a characteristic diagram, from which the regulating unit **34** (FIG. **3**) reads out the ignition time point to be selected which is then set directly at the internal combustion engine **8**, independently of which ignition time point ZZP_i was set in the preceding crankshaft revolution.

As an alternative, it can also be practical to evaluate the magnitude of the ignition time point adjustment and to apply it by way of actuating elements to the ignition time point ZZP_i which had already been set for a preceding crankshaft revolution.

In another, independent refinement of the invention, it is provided to perform the switch-off of the rpm lock circuit **33** as a function of the ignition time point ZZP_i itself which is set by the rpm lock circuit **33**. To this end, as shown in the flow diagram according to FIG. **7**, the engine is started in field **70** and the instantaneous rotational speed n_{act} is compared with an activation rotational speed n_{active}. The decision diamond **71** branches downward and activates the rotational speed controller only when the instantaneous rotational speed n_{act} is greater than the activation rotational speed n_{active}, by way of which rotational speed controller, for example, the ignition time point is set by a PI regulation in such a way that a setpoint rotational speed n_{set} is achieved. The ignition time point which is set by the rotational speed controller according to field **72** is compared with the ignition time point $ZZP_{deactive}$ in the decision diamond **73**, which leads to a deactivation of the rotational speed limit if the ignition time point ZZP_i which is set is greater than the ignition time point $ZZP_{deactive}$ which is predetermined as limit.

It is advantageously provided according to the decision diamond **73** that a plurality of ignition time points ZZP_i which follow one another are summed and a mean value is formed which is then compared with the ignition time point $ZZP_{deactive}$. If the mean value of the ignition time point, which is set of revolutions of the crankshaft which follow one another exceeds the predetermined ignition time point $ZZP_{deactive}$, the decision diamond **73** branches to a counter **74** which counts up by one increment, is increased by one in the present embodiment. If the averaged ignition time point lies below the deactivation threshold of the ignition time point $ZZP_{deactive}$, the decision diamond **73** branches back.

If the counter **74** reaches a limit value $z_{deactive}$, the rpm controller **33** is deactivated in accordance with the decision diamond **75**, as shown in field **76**. If the counter level (z) lies below $z_{deactive}$, the decision diamond **75** branches back before the decision diamond **73** for forming the mean value of the ignition time point ZZP_i.

It has been shown to be practical that satisfactory results are achieved if the ignition time point ZZP_i is averaged over from 2 to 25, preferably over 10 crankshaft revolutions which follow one another. The index (m) is therefore selected to be between 2 and approximately 25.

As FIG. **8** shows, the start of the internal combustion engine **8** takes place with start throttle in section **80**. The ignition time point lies at a very retarded time, at approximately 10° crank angle CA after the top dead center TDC of the piston **10** in the embodiment which is shown. If the user applies more throttle, that is, if the throttle valve **18** is open, fuel/air mixture is fed in increasingly; this leads to a further retardation, adjustment of the ignition time point ZZP to values of from approximately 20° to 25° CA in section **81**. The instantaneous rotational speed n_{act} of the internal combustion engine **8** is regulated downward to a pronounced extent via the rpm lock circuit **33**. If the load state changes from full load to idling, which is indicated at the dashed line **82**, this results in section **83** in a change in the mixture quantity which is fed in, with the result that, in order to maintain the rotational speed, the ignition time point is adjusted, in particular, suddenly from retarded ignition in section **81** to advanced ignition, in section **83**. The ignition time point ZZP exceeds the deactivation threshold $ZZP_{deactive}$ of the ignition time point which lies at approximately 5° before top dead center in the embodiment. If the ignition time point ZZP_i remains in the region of advanced adjustment, on the other side of the ignition time point $ZZP_{deactive}$ of the deactivation threshold over a predefinable number of revolutions of the crankshaft, the rpm lock circuit **33** is switched off. Switch-off therefore always takes place when the ignition time point ZZP_i which is set by the rpm lock circuit **33** lies earlier than the predetermined ignition time point $ZZP_{deactive}$. When the rpm lock circuit **33** is switched off, the ignition time point ZZP_i is constant and lies in the region of the predetermined ignition time point $ZZP_{deactive}$ approximately from 3° to 7° CA before top dead center.

The switch-off of the rpm lock circuit **33** advantageously takes place only when the ignition time point ZZP_i lies on the other side of the predetermined ignition time point $ZZP_{deactive}$ in a plurality of crankshaft revolutions which follow one another, that is, the state of advanced ignition prevails over a predetermined time period.

It can expediently be provided that a counter **74** is counted up by one increment each time the predetermined ignition time point $ZZP_{deactive}$ is exceeded, in order then to switch off the rpm lock circuit **33** when a counter limit value $z_{deactive}$ is reached. By way of example, the counter or the counter limit value $z_{deactive}$ also ensures that the rpm lock circuit **33** is not switched off immediately when a switch-off criterion is present, but rather that switch-off of the rpm lock circuit **33** preferably takes place only when the switch-off criterion is present over a predetermined time period Δt (FIG. **8**). The time period Δt can be defined in different ways, for example by elapsing of a timing element, by running up of a counter, by a predetermined number of crankshaft revolutions or the like.

The formation of a mean value over the ignition time point ZZP_i of a plurality of crankshaft revolutions which follow one another ensures that outliers are eliminated and natural idling has been set with high certainty in section **83**.

For full load detection, it can be practical to also provide switch-off in the case of extreme retarded ignition in a manner which corresponds to the switch-off in the case of advanced ignition; the predetermined ignition time point $ZZP'_{deactive}$ is selected correspondingly, in the region of retarded ignition at from approximately 10° to 12° after the top dead center (TDC) of the piston **10** in the embodiment which is shown according to FIG. **8**. The rpm lock circuit **33** is switched off when the ignition time point ZZP_i which is set lies later by one time or multiple times than the predetermined ignition time point $ZZP'_{deactive}$.

In a further independent refinement of the invention, the switch-off of the rpm lock circuit **33** can also take place as a function of the ignition time point shift ΔZZP. If the magnitude of the ignition time point shift ΔZZP lies above a predetermined value, the switch-off of the rpm lock circuit **33** cakes place. Thus, deactivation of the rpm lock circuit **33** can already take place when the jump from retarded ignition to advanced ignition takes place, as is shown in FIG. **8** by way of the double arrow for the ignition time point shift ΔZZP.

In the embodiment according to FIG. **9**, the deactivation of the rpm lock circuit **33** is carried out as a function of the off-cycle ratio ASR. Start throttle prevails in the first section **90**; ignition is triggered only every fourth crankshaft revolution; the off-cycle ratio ASR lies at 75%.

Full load prevails in the following section **91**. The user has increased the throttle from the start throttle, in order to release the start throttle latching. The increased mixture feed leads to an even more pronounced off-cycle; ignition is carried out only every fifth crankshaft revolution; the off-cycle ratio ASR lies at 80%.

During the change from full load from section **91** into idling of section **92**, the off-cycle ratio ASR falls significantly from 80% to 50%, that is to say an ignition is triggered during idling every second crankshaft revolution; the off-cycle ratio ASR lies at 50%. In order to switch off an rpm lock circuit **33**, the off-cycle ratio ASR can therefore be monitored, in order to switch off the rpm lock circuit **33**, if a deactivation threshold **93** is undershot or is exceeded in another context, since natural idling can then be assumed.

FIG. **10** shows a flow diagram for detecting a combustion pattern. The combustion pattern detection is active only when the instantaneous rotational speed n_{act} lies below the engaging rotational speed n_K. The decision diamond **100** is provided accordingly.

If the instantaneous rotational speed n_{act} lies below the engaging rotational speed n_K, the rotational speed difference Δn is defined from the instantaneous rotational speed n_{act} and the rotational speed n_{m-1} of the preceding crankshaft rotational speed (field **109**). If the determined rotational speed Δn is greater than a predetermined differential value n_D, combustion operation is present; the decision diamond **101** branches to the right to the field **102** 'Ignition with combustion'.

If Δn lies below the predetermined differential rotational speed n_D, no combustion operation has taken place, despite ignition, and the decision diamond **101** branches downward into the field **103** 'Ignition without combustion'.

If a combustion operation can be determined, a "1" is input via the field **102** into the shift register **104**; if there is no combustion operation, a "0" is fed in via the field **103** into the shift register. In this way, a "0" or a "1" which follow one another as a row is stored in the shift register as a function of combustion operations which have taken place per revolution of the crankshaft.

The content of a window **105** of the shift register **104** is fed to a pattern detection means which detects via the decision diamond **106** in comparison with predetermined patterns whether there is idling or whether there is full load. If the window **105** has, for example, the content 1 0 1 0 0 1 0 1 0 0 1 1 which is shown in FIG. **10**, there is an idling combustion sequence; the internal combustion engine is in natural idling. An rpm lock circuit can then be switched off.

If, in contrast, the window **105** shows a row of 1s which follow one another, an ignition and combustion process take place with every revolution of the crankshaft, with the result that a full load combustion sequence can be detected; the internal combustion engine is in full load.

The window **105** is designed in such a way that a predetermined number of crankshaft revolutions which follow one another are detected with or without combustion. In the embodiment which is shown, 13 crankshaft revolutions which follow one another are detected; it can be practical to use more or fewer crankshaft revolutions in order to form a combustion pattern.

The load state of the internal combustion engine **8** can be read off at the outputs (**107**, **108**) of the decision diamond **106** as a function of the pattern detection; a rpm lock circuit can therefore be deactivated as a function of the signals of the outputs (**107**, **108**).

It is understood that the foregoing description is that of the preferred embodiments of the invention and that various changes and modifications may be made thereto without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A method of controlling the rotational speed of a combustion engine in a handheld work apparatus, wherein the combustion engine is supplied with a fuel/air mixture; the combustion engine has a crankshaft configured to drive a work tool via a clutch configured to engage in dependence upon the rotational speed of the combustion engine; the clutch being configured to generate a drive connection with the crankshaft when above an engaging rotational speed (n_K) and to interrupt the drive connection when below the engaging rotational speed (n_K); the combustion engine further having a combustion chamber and a spark plug arranged in the combustion chamber; the combustion engine further having an ignition unit for driving the spark plug and an rpm lock circuit configured as a closed-loop control circuit; the rpm lock circuit being further configured to switch on when the combustion engine is started and to set the instantaneous rotational speed (n_{act}) of the combustion engine below the engaging rotational speed (n_K) of the clutch and, for this purpose, the rpm lock circuit further being configured to change a control variable and adapt operating parameters of the combustion engine in accordance with the value of the control variable to change the instantaneous rotational speed (n_{act}); the control variable being a control quantity or a manipulated variable, the method comprising the step of:

switching off the rpm lock circuit when the absolute value of the control variable for adapting the operating parameters drops below a lower limit value (G_{min}) or exceeds an upper limit value (G_{max}).

2. The method of claim **1**, wherein the rpm lock circuit is switched off when the manipulated variable or control quantity of the control loop lies outside a predetermined bandwidth; and, the bandwidth is defined by at least one of an absolute lower limit value (G_{min}) and an absolute upper limit value (G_{max}).

3. The method of claim **1**, wherein the control quantity is the amount of air supplied to the combustion engine.

4. The method of claim **1**, wherein the control quantity is the amount of fuel supplied to the combustion engine.

5. The method of claim **1**, wherein the control quantity is the ignition time point (ZZP).

6. The method of claim **1**, wherein the control quantity is the off-cycle ratio (ASR) of the ignition.

7. The method of claim **1**, wherein the fuel metering is controlled by a fuel valve and the actuating variable is the open time of the fuel valve.

8. The method of claim **1**, wherein the actuating variable is the number of sequential crankshaft revolutions with an ignition.

9. The method of claim **1**, wherein the actuating variable is the absolute ignition time point (ZZP).

10. The method of claim **1**, wherein the actuating variable is the magnitude of the ignition time point shift.

11. The method of claim **1**, wherein the work apparatus is one of a chain saw, a cutoff machine, a hedge trimmer and a blower.

12. A method for controlling the rotational speed of a combustion engine in a handheld work apparatus, wherein the combustion engine has a combustion chamber delimited by a piston with a fuel/air mixture being metered to the combustion chamber, the combustion engine has a crankshaft configured to drive a work tool via a clutch configured to engage in dependence upon the rotational speed (n) of the combustion engine; the clutch being configured to generate a drive connection with the crankshaft when above an engaging rotational speed (n_K) and to interrupt the drive connection when below the engaging rotational speed (n_K); the combustion engine further having a spark plug arranged in the combustion chamber; an ignition unit for driving the spark plug so as to cause an ignition spark to be triggered relative to the angular position of the crankshaft; an rpm lock circuit configured as a closed-loop control circuit; the rpm lock circuit being further configured to switch on when the combustion engine is started and to set the instantaneous rotational speed (n_{act}) of the combustion engine below the engaging rotational speed (n_K) of the clutch; the rpm lock circuit is configured to change the ignition time point (ZZP) of the spark plug to change the instantaneous rotational speed (n_{act}) of the combustion engine as a manipulated variable; the method comprising the steps of:

providing a pregiven ignition time point ($ZZP_{deactive}$);

with each rotation of the crankshaft, comparing the ignition time point (ZZP) set by the rpm lock circuit to the pregiven ignition time point ($ZZP_{deactive}$); and,

switching off the rpm lock circuit when the set ignition time point (ZZP) exceeds the pregiven ignition time point ($ZZP_{deactive}$) over several sequential revolutions of the crankshaft.

13. The method of claim **12**, wherein a counter is increased by one increment when the pregiven ignition time point ($ZZP_{deactive}$) is exceeded and the rpm lock circuit is switched off when a counter limit value (z_G) is reached.

14. The method of claim **12**, wherein the pregiven ignition time point ($ZZP_{deactive}$) lies ahead of top dead center of the piston.

15. The method of claim **12**, wherein the ignition time point (ZZP_i) determined by the rpm lock circuit per crankshaft revolution is averaged over several sequential crankshaft revolutions.

16. The method of claim **12**, wherein said rpm lock circuit determines a control variable in dependence upon the instantaneous rotational speed (n_{act}) of the combustion engine.

17. The method of claim **12**, wherein the rpm lock circuit determines a control variable in dependence upon the difference of the instantaneous rotational speed (n_{act}) of the combustion engine and a pregiven limit rotational speed (n_G).

18. The method of claim **12**, wherein the work apparatus is one of a chain saw, a cutoff machine, a hedge trimmer and a blower.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,322,329 B2
APPLICATION NO. : 13/956088
DATED : April 26, 2016
INVENTOR(S) : Gegg et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Specification

In column 7:
Line 37: delete "**36**" and substitute -- **37** -- therefor.
Line 43: delete "ZZP_j" and substitute -- ZZP_i -- therefor.

In column 9:
Line 41: delete "cakes" and substitute -- takes -- therefor.

Signed and Sealed this
Second Day of August, 2016

Michelle K. Lee
Director of the United States Patent and Trademark Office